Chemical Quantities

Chapter 10

Molar Mass

- Molar mass is the sum of atomic masses of the elements in the compound.
  - You MUST take into account the number of atoms of each element.

Example: $Ca_3(PO_4)_2$

Ca 3(40.08)

P 2(30.97)

+O 8(16.00)

310.18 g $Ca_3(PO_4)_2$

Significant figure rules:

- when adding or subtracting keep the smallest number of decimal places.
- The number of atoms is a counted quantity and has infinite significant figures.

Equality Statements

- Chemistry requires converting between different units of measure.
- Mole (mol) is the amount of a substance and can be used to show relationships between other units.
- 1 mol = 22.4 L {of any gas at STP}
- 1 mol = 6.02 x 1023 particles (ptl)
- 1 mol = molar mass g

Equality Statements

- Note STP means standard temperature and pressure.
  - Which is 1 ATM and 273 K
- Molar mass is measured in grams and students must find it for each chemical formula.
- Particles can include:
  - Atoms (unique to elements)
  - Molecules (unique to covalent compounds) (mlc)
  - Ions (unique for ions)
  - Formula Units (unique for ionic compounds) (F.U.)

One Step conversions

- Chemistry conversions are all about canceling out the undesired unit to get the desired unit.
- When doing conversion you MUST show
  - Numbers
  - Units {mol, mlc, F.U, g, L}
  - Chemical Formulas {example: $Ca_3(PO_4)_2$}
- Steps
  1. Write number and unit given in the problem
  2. Multiply by a fraction so that units cancel

  What every your getting rid of goes on bottom, what every our going to goes on top.

  3. Add the correct numbers form your equality statments.

One Step Conversions

- All examples are for $Ca_3(PO_4)_2$
  - where 1 mol $Ca_3(PO_4)_2$ = 310.18 g $Ca_3(PO_4)_2$
- Example 1: find number of grams in 1.846 moles

$$1.846\ molCa_3(PO_4)_2 \times \frac{310.18\ gCa_3(PO_4)_2}{1\ molCa_3(PO_4)_2} = 572.6\ gCa_3(PO_4)_2$$

- Example 2: find number of moles in 267.53 g $Ca_3(PO_4)_2$

$$267.53gCa_3(PO_4)_2 \times \frac{1\ molCa_3(PO_4)_2}{310.18gCa_3(PO_4)_2} = 0.86250\ molCa_3(PO_4)_2$$

- Example 3: find number of moles in 1.23 x 10^{25} F.U. $Ca_3(PO_4)_2$

$$1.23 \times 10^{25} F.U.Ca_3(PO_4)_2 \times \frac{1\ molCa_3(PO_4)_2}{6.02\ \times\ 10^{23} F.U.Ca_3(PO_4)_2} = 20.4\ molCa_3(PO_4)_2$$

NOTE that the staring unit determines the location of the units in the conversion fraction.

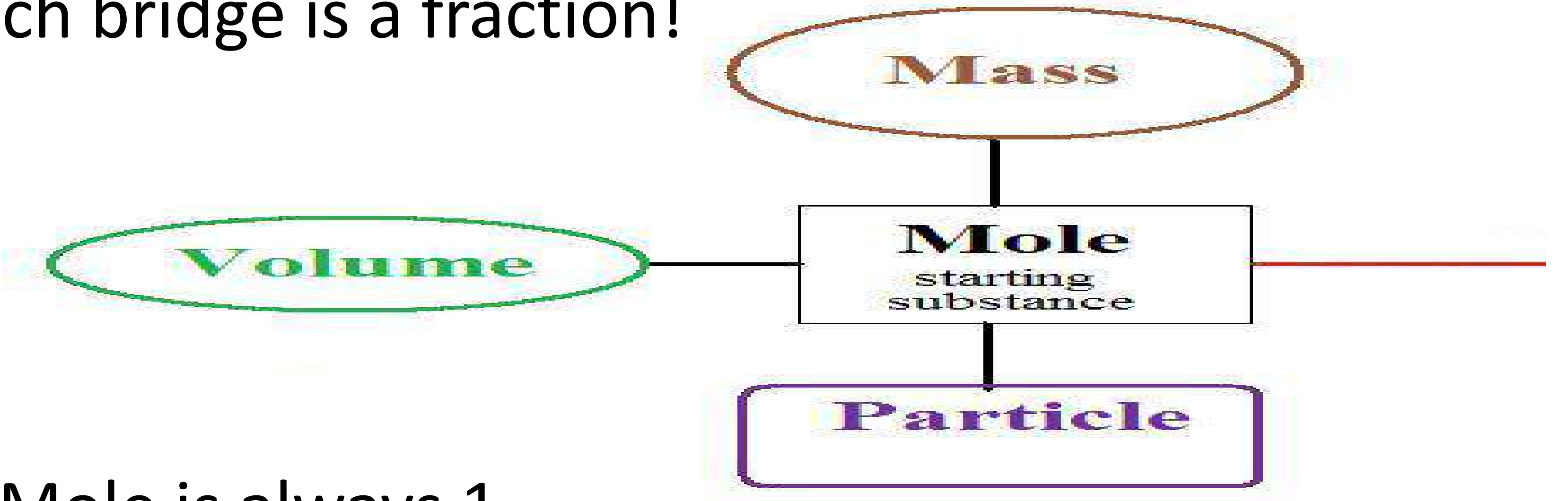
Two Step Conversion

- Only allowed to convert using the equality statements below
  - 1 mol = 22.4 L {of any gas at STP}
  - 1 mol = 6.02 x 1023 particles (ptl)
  - 1 mol = molar mass g
- When going from grams to L or particles to grams (ect) it requires two conversion factions.
- The order of the units in the fractions are determined by what you are starting with and what you want to go to.

Two Step Conversion

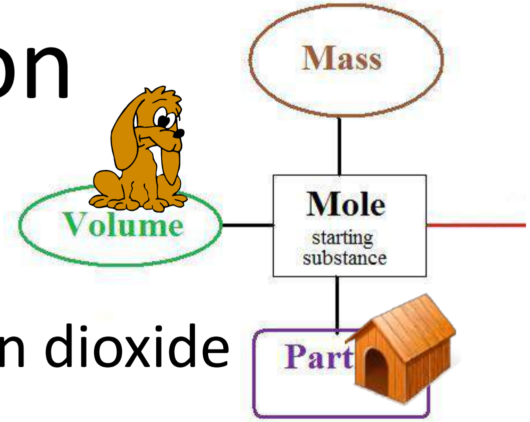
Raines Mole Map

Each bridge is a fraction!



- Mole is always 1
- Volume is always 22.4 L
- Particles is always 6.02×10^{23} ptl
- Mass is always molar mass of compound/element in grams.

Two Step Conversion



- Example 1

Find the number of particles in 0.0534 L of carbon dioxide

Turn name into formula: carbon dioxide is CO_2

Use map to see how many steps it will take to complete conversion.

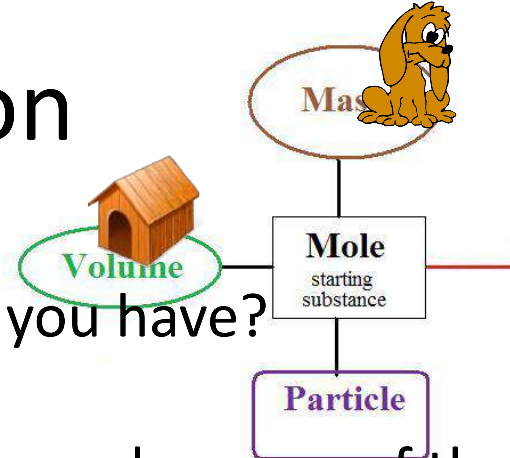
Two bridges means two fractions.

Write given number and unit with chemical formula then set up fractions so that units cancel.

$$0.0534\ L\ CO_2 \times \frac{mol CO_2}{L CO_2} \times \frac{ptl CO_2}{mol CO_2} =$$ fill in fractions with # from equality statements

$$0.0534\ L\ CO_2 \times \frac{1\ mol CO_2}{22.4\ L CO_2} \times \frac{6.02 \times 10^{23} ptl\ CO_2}{1\ mol\ CO_2} = 1.44 \times 10^{21}\ ptl\ CO_2$$

Two Step Conversion



- Example 2

If you have 55.6 g of propane (C_3H_8) how liters do you have?

This problem involves mass and you must calculate molar mass of the compound.

C= 3(12.01g)   H= 8(1.01g)   Total: 3(12.01g)+ 8(1.01g)=23.09 g C_3H_8

This means 1 mol C_3H_8 = 23.09 g C_3H_8

Set up conversion by canceling units.

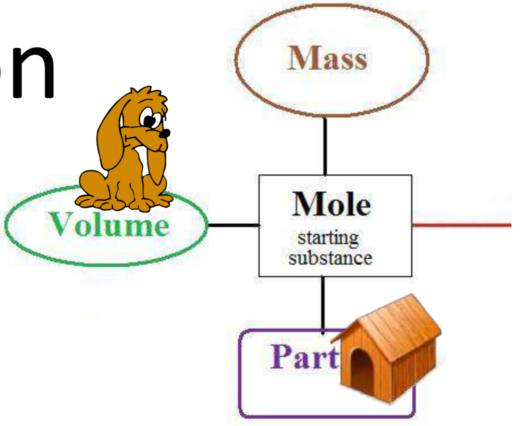
$$35.6g\ C_3H_8 \times \frac{mol C_3H_8}{g C_3H_8} \times \frac{L\ C_3H_8}{mol\ C_3H_8}$$

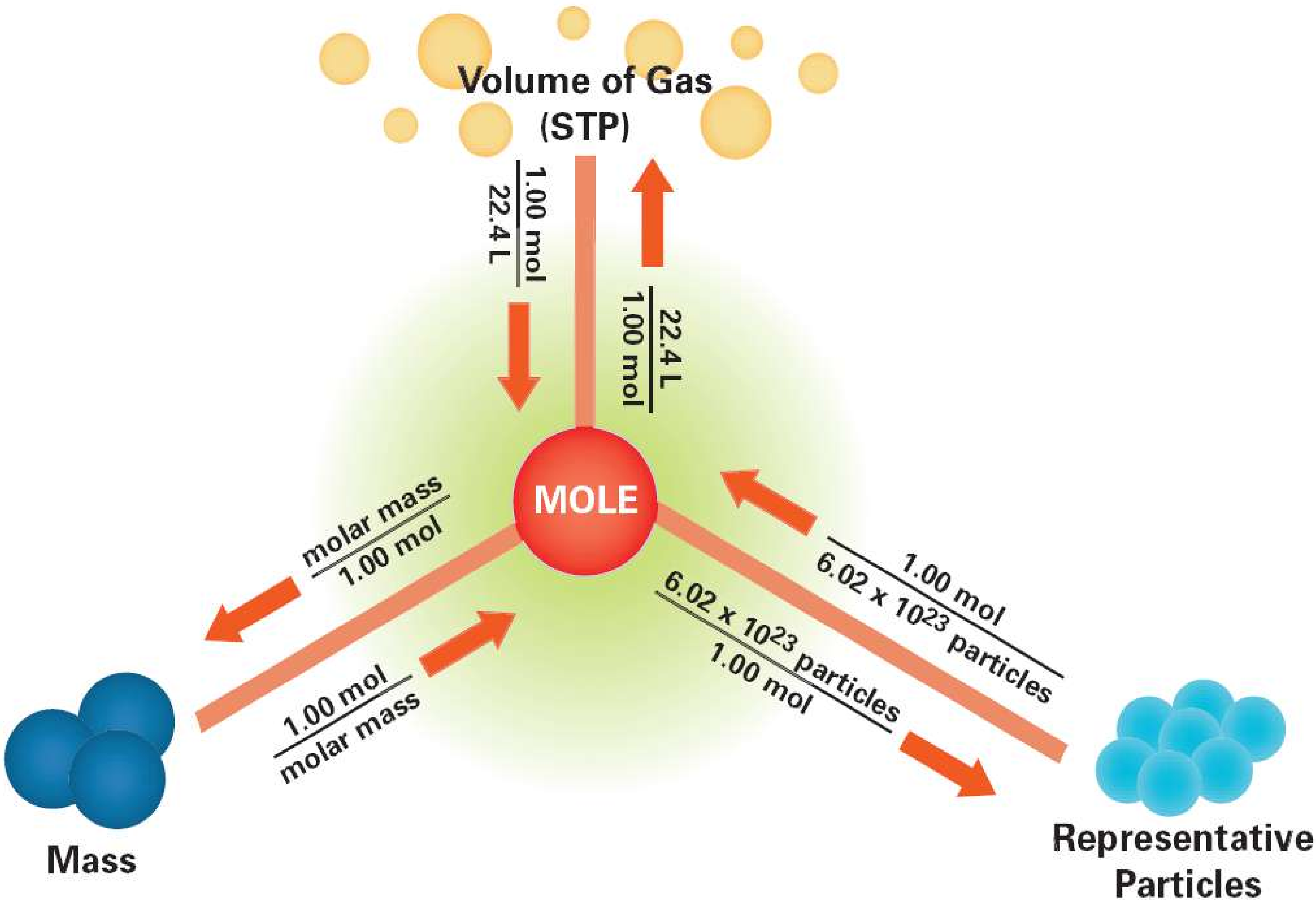
complete fractions with numbers from equality statements

$$55.6g\ C_3H_8 \times \frac{1\ mol\ C_3H_8}{23.09g\ C_3H_8} \times \frac{22.4\ L\ C_3H_8}{1\ mol\ C_3H_8} = 53.9\ L\ C_3H_8$$

Two Step Conversion

- Example 1





Text book mole map

Percent composition

- Percent composition is the relative amount of the elements in a compound
- The percent by mass of an element in a compound is the number of grams of the element divided by the mass in grams of the compound, multiplied by 100
- $\%\ mass\ of\ element = \dfrac{mass\ of\ elemnt}{mass\ of\ compund} x\ 100$
- **You can check if you did correctly by adding up the % compositions. It should equal 100 (or be very close 99.98 to 100.02 range):**

Percent Composition Example 1

Find the percent composition of each element in H_2O

- Mass of H_2O = 2(1.01)+1(16.00)=18.02g
- Mass of hydrogen in H_2O = 2(1.01) =2.02 g
  - % comp of hydrogen = 2.02g/18.02g x 100= **11.21% hydrogen**
- Mass of oxygen in H_2O = 1(16.00)=16.00 g
  - % comp of oxygen = 16.00g/18.02g x 100= **88.79% oxygen**
- **Check:** 11.21% hydrogen **+** 88.79% oxygen = 100 % total so work was correct

Percent Composition Example 2

Find the percent composition of each element in $Ca_3(PO_4)_2$

- Mass of $Ca_3(PO_4)_2$= 3(40.08) + 2(30.97) + 8(16.00)= 310.18 g
- Mass of Calcium in $Ca_3(PO_4)_2$ = 3(40.08) = 120.24 g
  - % comp of calcium = 120.24g/310.18g x 100 = **38.76 % Ca**
- Mass of phosphorous in $Ca_3(PO_4)_2$ = 2(30.97) = 61.94 g
  - % comp of phosphorous = 61.94 / 310.18 x 100 = **19.97% P**
- Mass of oxygen = 8 (16.00) = 128.00 g
  - % comp of oxygen = 128.00g /310.18g x 100 = **41.27% O**
- Check: 38.76 % + 19.97% + 41.27% = 100%

Percent composition

$$\%\ composition\ of\ element = \frac{mass\ of\ element}{mass\ of\ compund} x\ 100$$

or

$$\%\ composition\ of\ element$$
$$= \frac{\#\ atoms\ (atomic\ mass)}{mass\ of\ compound} x\ 100$$

remember to check your work by adding up the percentages

Percent composition with masses

- Finding percent composition if given the mass of the elements in the compound is the same process.
- $\%\ composition\ of\ element = \dfrac{mass\ of\ element}{mass\ of\ compund} x\ 100$
- Example: find the percent composition of each element if the compound containing 27.53 g of Ca and 48.72 g of Cl
  - $\%\ Ca = \dfrac{27.53}{27.53 + 48.72} x\ 100$= 36.10 % Ca
  - $\%\ Cl = \dfrac{48.72}{27.53 + 48.72} x\ 100$= 63.90 % Cl

Using Percent Composition

- If you know the percent composition (or can calculate it) it can be used to find the mass of an element in compound.
- total Mass (% in decimal form) = mass of element
- Example: You have a 58.24 g sample of a substance that contains 25.0% hydrogen. What is the mass of hydrogen in the sample
  - 58.24g (.0250)=14.56 g hydrogen

Using Percent Composition

- If give the chemical name or formula you will need to find the percent composition of the desired element.
- Example: You have a 27.80 g sample of aluminum sulfide, what is the mass of aluminum in the sample.
  - Al_2S_3
  - Molar mass: 2(26.98) + 3(32.07) = 150.17g
  - % Al = $\frac{2(26.98)g}{150.17g} \times 100 = 35.93$ % Al
  - 27.80g (0.3593) = 9.99 g of sample is Al

Empirical formula

- Empirical formula gives the lowest whole-number ratio of the atoms of the elements in a compound
- An empirical formula may or may not be the same at a molecular formula
- **The empirical formula of a compound shows the smallest whole-number ratio of the atoms in the compound**
- Example: methane is C_2H_6, empirical formula would be CH_3.

Finding Empirical Formulas

1. **IF** given % assume you have a 100 g sample and the % turns into grams.
2. Turn grams of each element into moles of the element. (use mass to mole conversion).
3. Get whole number ratio of elements. (Divide all by smallest # of moles)
4. Use whole numbers as subscripts in chemical formulas

Empirical formula example 1

- Find empirical formula for compound containing 67.7% mercury, 10.8% sulfur, and 21.6% oxygen.

1. 67.7 g Hg, 10.8 g S, 21.6 g O
2. Mole Hg= 67.7gx (1mol/200.59g) =0.34 molHg
   Mol S = 10.8 g x (1mol/32.07g)=0.34 mol S
   mol O = 21.6 g x (1mol/16.00g)= 1.35 mol O
3. # of Hg = (0.34/0.34) = 1 Hg
   # of S = (0.34/0.34) = 1 S
   # of 0 = (1.35/0.34) = 3.97 = 4 O
4. $HgSO_4$

Empirical Formula

- When you find the ratio of atoms be on the look out for numbers that indicate you have to multiply.
  - Ratios of 1.5, 2.5 …. Indicate you need to multiply by 2
  - Ratios of 1.33, 2.33 … indicate you need to multiply by 3
- If your ratio is very close to the whole number round to the whole number. 1.02 would round to 1, 2.97 would round to 3.

Empirical formula example 2

- Find empirical formula for compound containing 62.1%C, 13.8 % H, 24.1%N.

1. 62.1 g C, 13.8 g H, 24.1 g N
2. mol C= 62.1g $\frac{1\ mol}{12.01\ g}$ =5.17 mol C

   mol H = 13.8 g $\frac{1\ mol}{1.01\ g}$ 13.66 mol H

   mol N = 24.1 g x $\frac{1\ mol}{14.01\ g}$ 1.72 mol N
3. # of C = (5.17/1.72) = 3.01 C = 3 C

   # of H = (13.66/1.72)= 7.94 H = 8 H

   # of N = (1.72/1.72) = 1 N
4. C_3H_8N

Molecular formula

- Molecular formula is also known as the TRUE formula.
- In order to find molecular formula you MUST know the MOLAR MASS of the compound.
- You must also calculate the value that the subscripts need to be multiplied by.
- Multiplier = $\dfrac{molar\ mass}{empirical\ mass}$

Molecular Formula Example 1

- Example: find the molecular formula if the molar mass of the compound is 174.36 and it's empirical formula is C_3H_8N
  - Empirical formula = C_3H_8N has mass of58.12g
  - Multiplier = $\frac{174.36}{58.12} = 3$ {multiply each subscript by this number}
  - Molecular formula = $C_9H_{24}N_3$

Example 2

- Find the empirical and molecular formula for a compound containing 40.0% C, 6.7% H, 53.3% O and a molar mass of 90.09 g.
- 1st use % to find empirical formula

$$40.0 \text{ g C} \times \frac{1\ mol}{12.01\ g} = 3.33\ mol\ C$$

$$6.7 \text{ g H} \times \frac{1\ mol}{1.01\ g} = 6.63\ mol\ H$$

$$53.3 \text{ g O} \times \frac{1\ mol}{16.00\ g} = 3.33\ mol\ O$$

Need to find whole number ratio of mole so divide each by smallest number of moles

Example 2

Whole # ratio

$$40.0\text{ g C} \times \frac{1\ mol}{12.01\ g} = 3.33\ mol\ C \div 3.33 = 1\ C$$

$$6.7\text{ g H} \times \frac{1\ mol}{1.01\ g} = 6.63\ mol\ H \div 3.33 = 1.99 = 2\ H$$

$$53.3\text{ g O} \times \frac{1\ mol}{16.00\ g} = 3.33\ mol\ O \div 3.33 = 1\ \text{O}$$

Empirical Formula = CH_2O

Empirical Mass = 12.01 + 2(1.01) + 16.00 = 30.03

Multiplier = $\frac{90.09g}{30.03\ g} = 3$

Molecular formula = $C_3H_6O_3$